NAVSTAR GPS Modernization Program

MCode Briefing to
GPS III Industry Days

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Why Modernization?

Protection

Prevention

Security

Overview

- Background
  - Protection
  - Prevention
  - Security
- M Code Signal Characteristics
  - Objectives and Constraints
  - Modulation
  - Acquisition Aid
  - Flexible Data Message
  - Security
- Summary & Conclusions

Protection

"To preserve military use of GPS…"

- GPS is integral to future operational effectiveness of United States
  - For communication, imagery, targeting, and timing - as well as navigation!
- Studies have quantified GPS antijam (AJ) performance
  - Cannot significantly raise Y Code power because of backward compatibility

Prevention

"…while preventing the hostile use of the civil signals."

- (92) Commercial receivers developed to exploit L_2 signal
- (5/95) National Research Council recommended second civil frequency
- (1/96) Presidential Decision Directive plans turn off of Selective Availability (accuracy degradation) by 2006
- (2/97) Dr. Kaminski guarantees L2 carrier phase for civil use

- Must deny use of GPS to the enemy in AOO without unduly affecting civilians outside of the AOO

Security

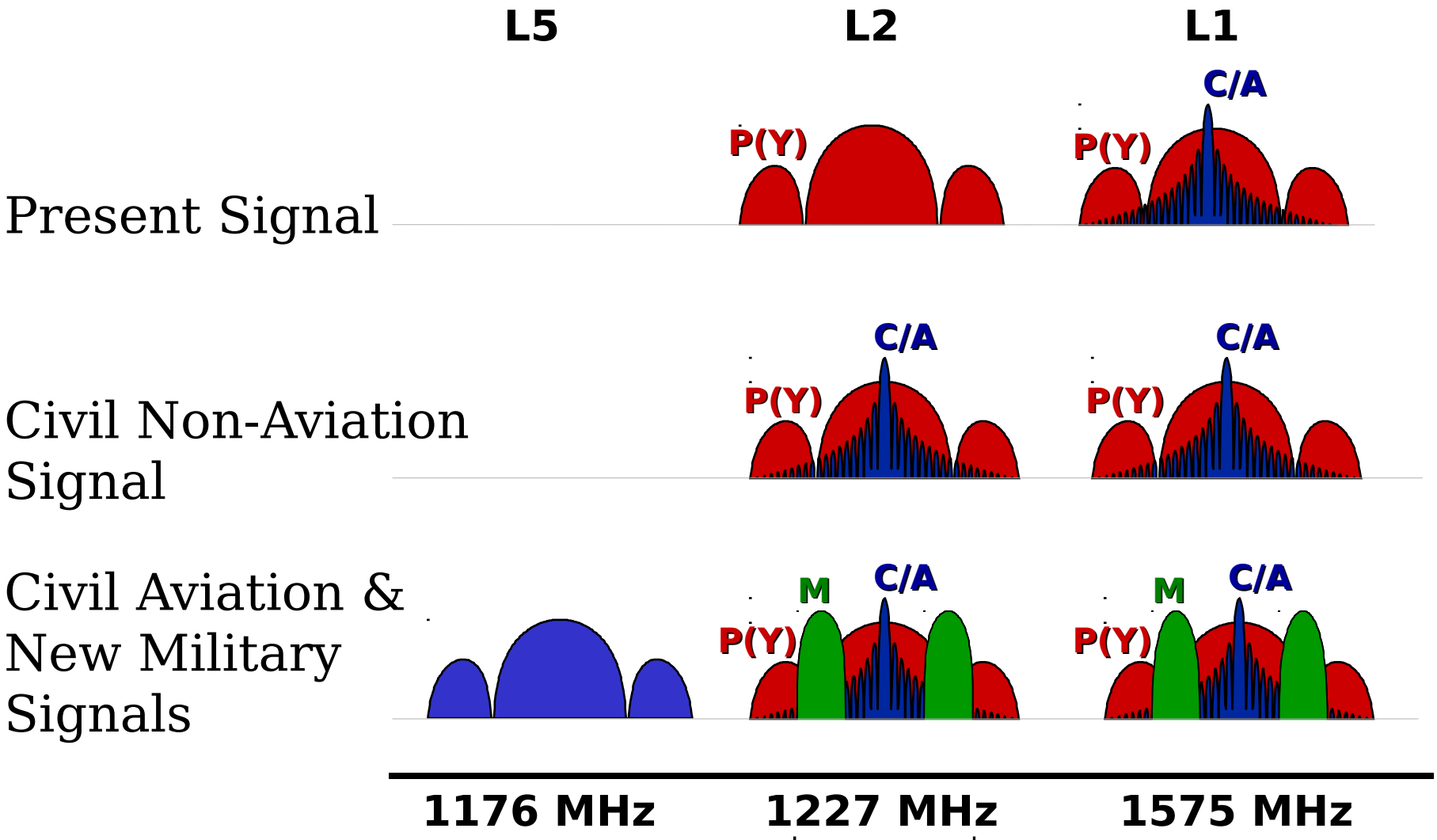
"To preserve the military use of GPS while preventing the hostile use of the civil signals."

- Security reaches across all aspects of GPS operations - both Prevention and Protection!
- Additional Information available on 10 May

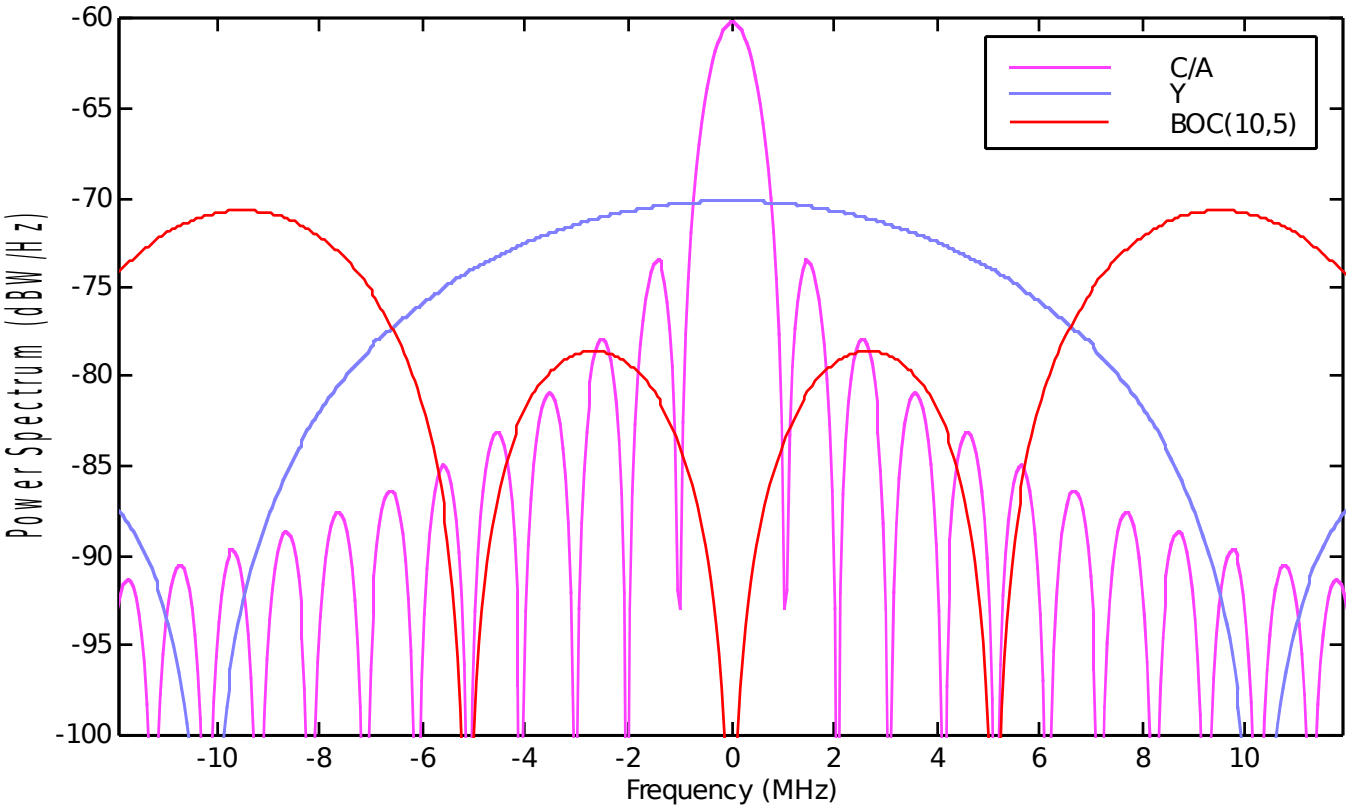
The M Code Signal

- Objectives
  - Better security (exclusivity, authenticity, confidentiality) against long-term vulnerabilities
  - Better or same performance as Y code at same power
  - Prevention compatibility
  - Better jamming resistance (the space contribution to system AJ)
- Constraints
  - Occupy existing frequency bands—coexist with current signals
  - Backward compatibility with Y code receivers
  - Minimize UE & integration costs

Modernized Signal Evolution

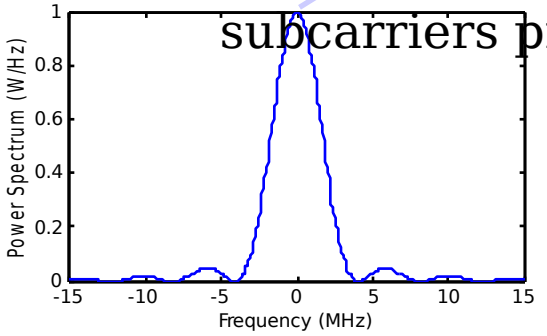


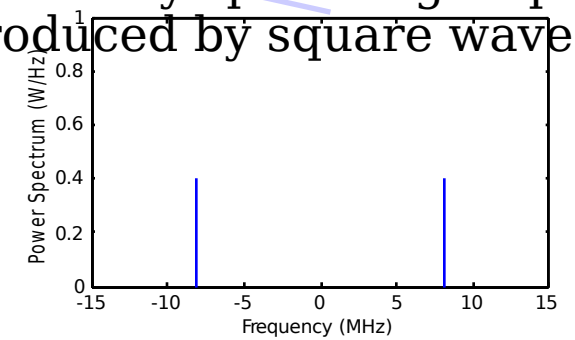
MCode Power Spectrum

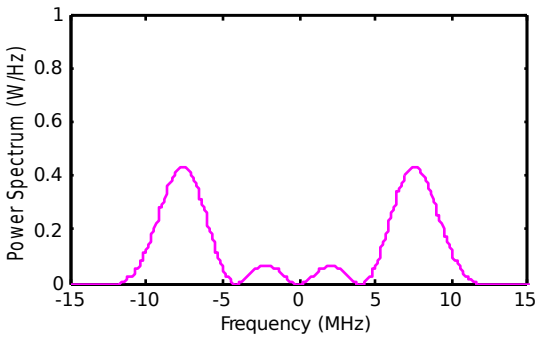


"Split Spectrum" Modulations

- ~~Constant envelope, biphase modulations for simpler~~ implementation
  - Designed to fit within 24 MHz, with spectral null around band center
- Modulation families called Manchester and Binary Offset Carrier (BOC)
- Variants of direct sequence spread spectrum signaling
  - Pseudorandom binary spreading sequence modulates subcarriers produced by square wave

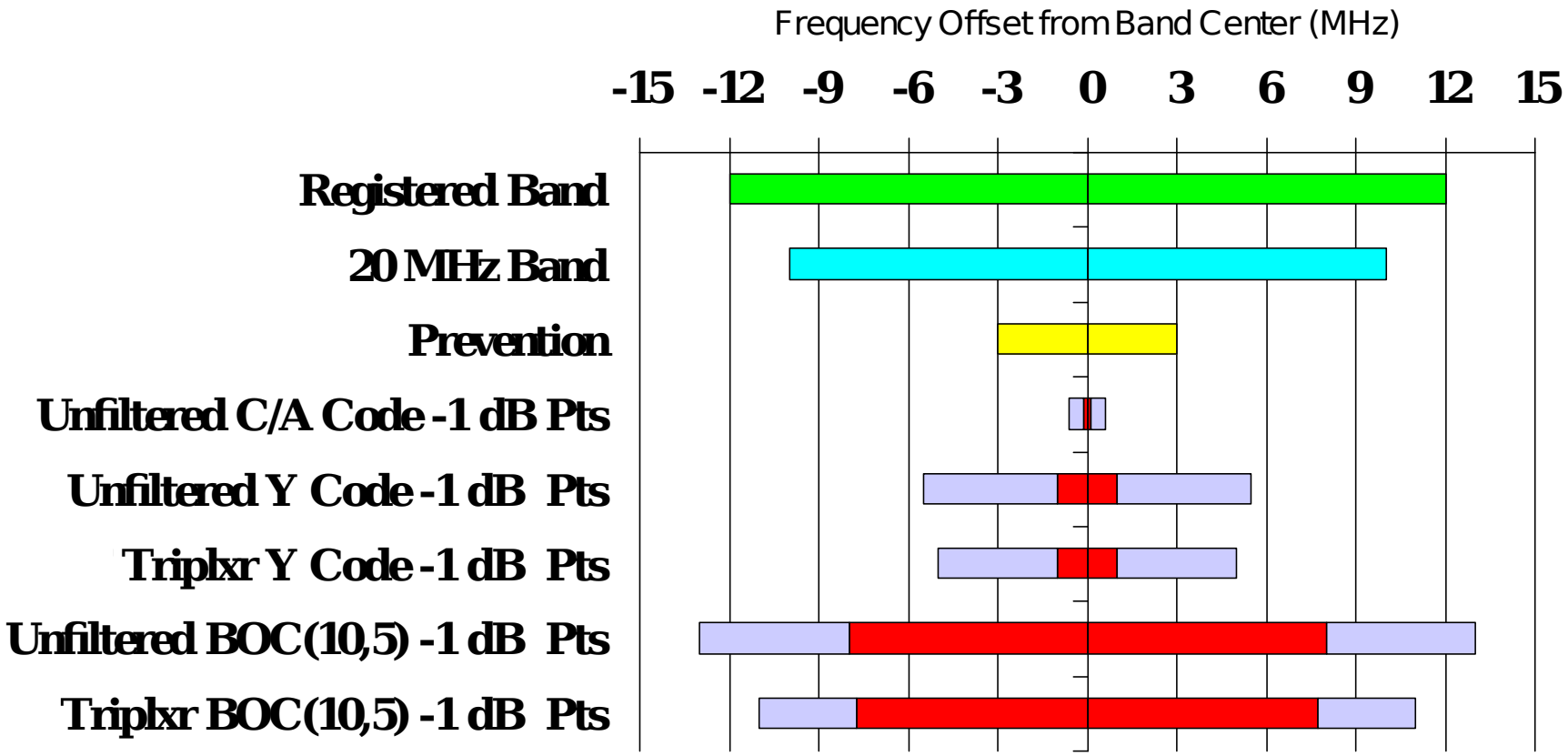






- Receiver can coherently process modulation on both subcarriers for processing gain and accuracy
- Receiver can process modulation on only one subcarrier ("single sideband reception") for simplicity

RF Bandwidth



- Cumulative –1 dB points calculated for filtered signals
  - 20% of power within red bar
  - 20% of power outside gray bars

Benefits of M Code Modulation

- Enables substantial increase in received power without degrading legacy UE
- Allows user to operate in Prevention and legacy jammer environments
- Increases pseudorange code tracking loop accuracy

Acquisition of the Signal

- Direct Acquisition
  - Preferred long-term approach for most signal acquisitions
- Aided Acquisition
  - Near-term or backup approach for stressing conditions
  - Embedded scheme for low AJ
  - Separate scheme for high AJ

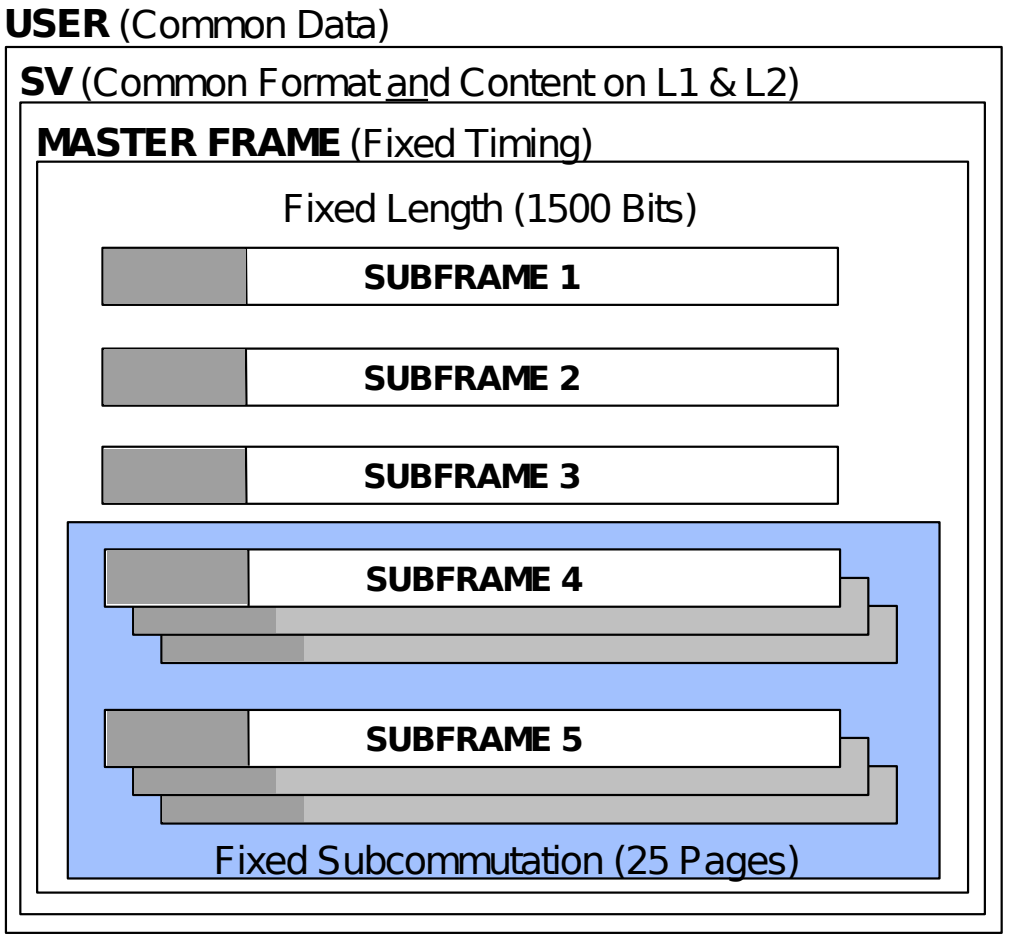
Benefits of M Code Acquisition

- Direct M vs Direct Y
  - Eases UE computational complexity by factor of 2
- Benefits of embedded acquisition scheme
  - Eases UE Complexity in low AJ
- Benefits of dedicated acquisition signal
  - Eases UE Complexity in high AJ
  - Backup into the system
    - Not relied on (i.e., ICD identifies it as an optional signal on some satellites)
  - Other

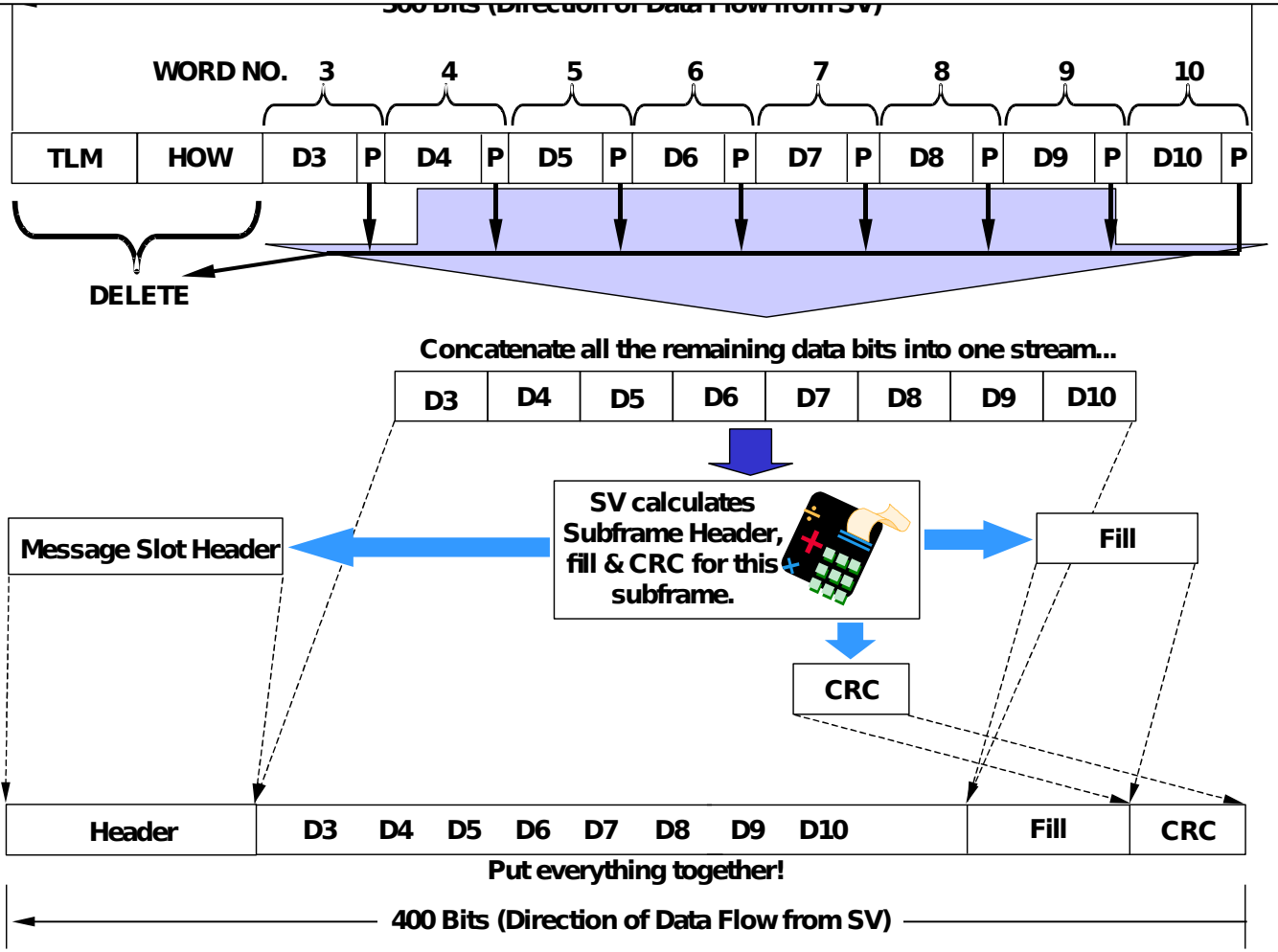
Current Data Message

Deficiencies/Limitations

- **Data Rate is Fixed (50 bps)**
- Shared by Military & Civilians
- **Common across all SVs**
- **Identical content on L1 & L2** (when present on L2)
- Tightly constrained timing of output & update
- Fixed Length
- **"Costly" Overhead**
  - TLM & HOW 20%
  - (32,26) Hamming parity
  - Subcommutation
- Antiquated technology basis (circa 1980)
- **At or Near "Saturation"**
- **Difficult to Modify**



From Subframes to Messages



Structure of an MNAV Message

Messages (instead of Subframes)

- Message Length = 400 Bits (instead of 300 Bits/SF)
- Each Message Possesses Three Parts:
  - Header
  - Data Field
  - Cyclic Redundancy Checkword (CRC)

Benefits of New MNav Message

- Flexible control of configuration and content
- Substantially increases availability of PVT data in jamming environment
- Offers greater over-the-air-rekey capability for the warfighter
- Reduces inefficiencies of current format by over 50%
  - Reduce time to transmit almanac from 12.5 minutes to 100 sec - over 1000% improvement
  - Reduce time to first fix by over 100%
- Modular User Equipment development
- Complete flexibility to incorporate future growth of GPS operational needs

Possible Uses of MNav Message

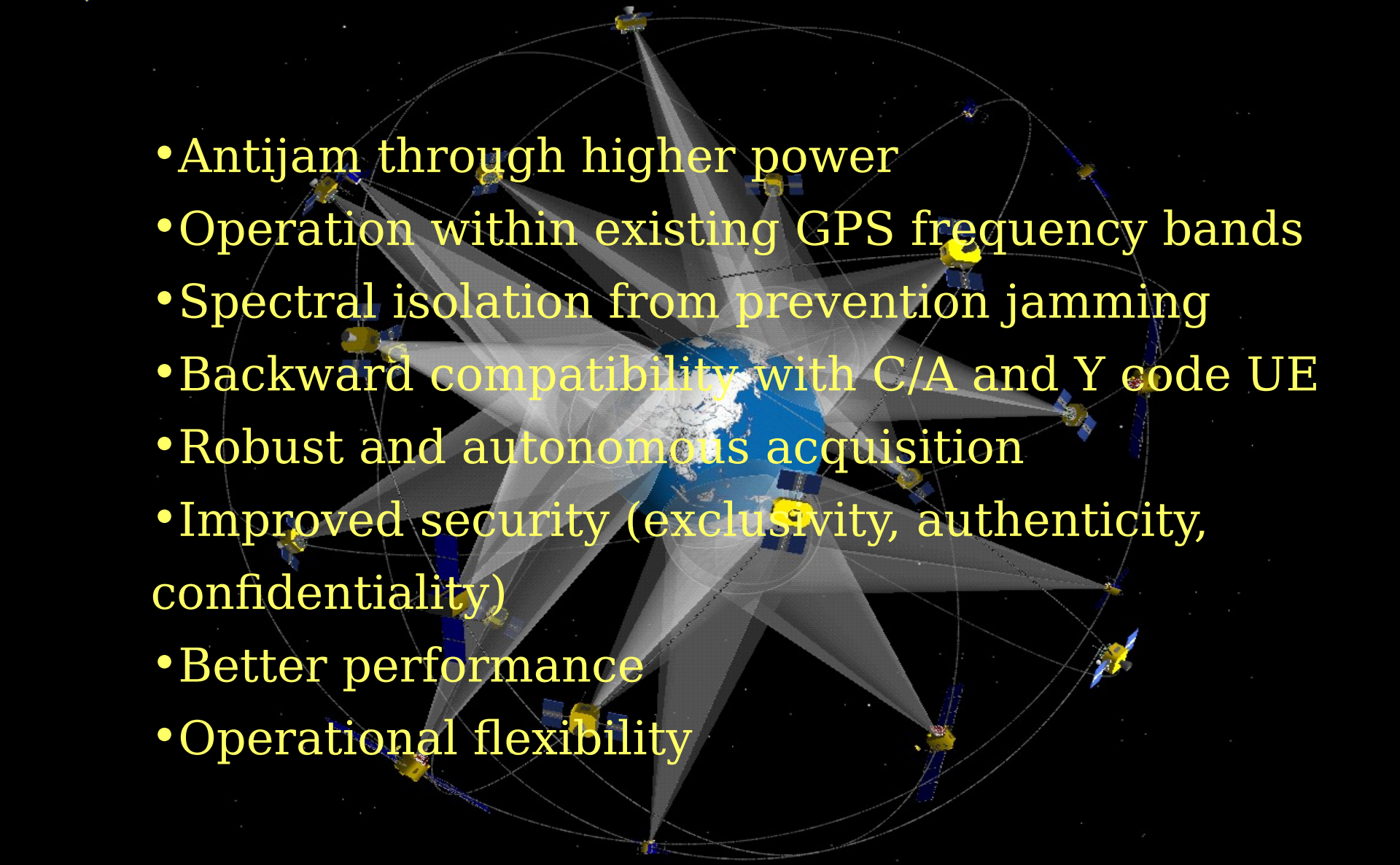
- Enhanced Single-Frequency Ionospheric Correction Model(s)
- System Integrity Service Messages
- Compressed Ephemeris & Clock Data Sets
- Improved UTC Time Distribution
- GPS Augmentation System Status
- Regional Atmospheric/Weather Data
- Theater GPS Electronic Warfare (EW) Disposition/Status
- Nuclear/Biological/Chemical Strike Warnings/Alerts
- Theater/Regional Differential Corrections
- Over-the-Air-NANUs
- Over-the-Air-Rekey (OTAR)
- Tactical Special Messages

NOTE: These are <u>potential</u> capabilities, not necessarily what <u>will</u> be provided

Security Features

- Expands the SAASM-based security enhancements
- New cryptographic algorithms
- Potential for separate simulator, pseudolite services
- Key architecture to be releasable to Allies
- More information/capabilities in classified session on 10 May

MCode



- Antijam through higher power
- Operation within existing GPS frequency bands
- Spectral isolation from prevention jamming
- Backward compatibility with C/A and Y code UE
- Robust and autonomous acquisition
- Improved security (exclusivity, authenticity, confidentiality)
- Better performance
- Operational flexibility

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